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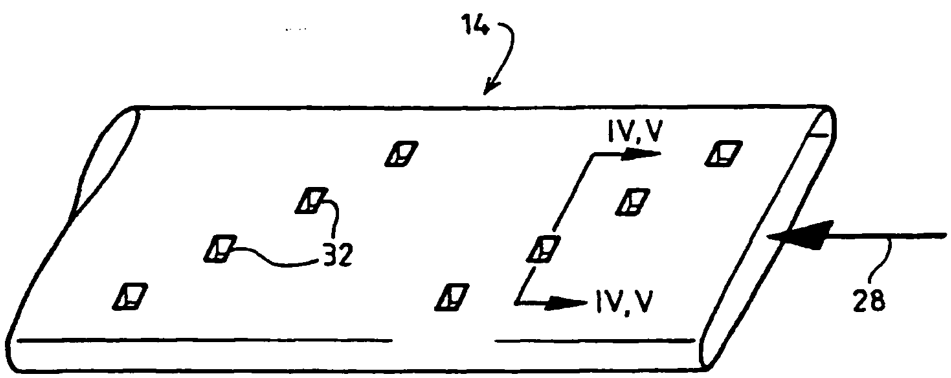
(54) Title: HEAT EXCHANGER TUBE



(57) Abstract: Coolant tubes (14) for heat exchangers are formed with projections (30) extending into the tube cross section to interfere with the fluid flow (28) and to ensure mixing of the coolant as it passes through the tubes. To achieve the necessary degree of mixing without causing the flow to become turbulent and thus to prevent unnecessary back pressure, the area of the tube wall occupied by projections (30) is less than 7.5% of the total area of the tube wall.

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HEAT EXCHANGER TUBE

This invention relates to heat exchangers for reducing the temperature of the coolant which circulates in a heat exchange circuit. In particular the present invention relates to tubes for conveying coolant through such heat exchangers, for example vehicle radiators, or through any tube/fin heat exchanger such as a heater core.

US patent 4 470 452 discloses a radiator tube which is constructed so as to produce turbulence in the coolant flow to improve the heat exchange characteristics between the coolant and the air which, in use, flows through the radiator and past the tubes. In that specification the radiator tubes disclosed have flow diverting members placed along the length of each principal heat transfer surface, with the principal heat transfer surfaces being bowed outwardly. The flow diverting members (which actually take the form of indentations or dimples pressed into the walls of the tubes) are present to provide turbulence in the coolant as it flows along the tube.

US Patent 2 017 201 describes a condenser tube which has a pair of parallel walls and inwardly extending transverse indentations which form transverse restrictions in the passage through the tube offset from the central plane of the tube. The presence of these indentations or ribs produces turbulence of the liquid circulating through the tubes.

I have now surprisingly found that better heat exchange between the coolant and the air can be achieved by substantially reducing, or even preventing, the production

of turbulence in the coolant, whilst producing the necessary mixing of the coolant under laminar flow conditions. Mixing means that coolant which at one moment is in contact with the tube wall moves from that position into the centre of the tube, and vice versa, this process taking place continuously to encourage uniform temperature distribution throughout the coolant. In the prior art, it was seen necessary to encourage turbulence to achieve this desirable uniform temperature distribution.

In addition to giving good mixing of the hot coolant in the tube, the absence of turbulence in my invention can also reduce the back pressure which the coolant experiences in flowing through the tubes. As a result, better heat transfer is achieved.

According to the invention there is provided a tube for conveying coolant through a heat exchanger, the tube having a flattened cross-section with two major opposing walls and internal projections on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube, wherein each projection extends across less than 30% of the width of the tube and the area of the tube walls having projections amounts to less than 7.5% of the total area of the tube walls.

By reducing the number of projections to this level it is possible (in comparison to the prior art) to reduce the resistance to coolant flow through the tube, and thus to reduce the back pressure experienced by the coolant, whilst still obtaining the necessary mixing of the

coolant.

The projections are preferably dimples formed in the tube walls, the dimples having substantially equal dimensions in the direction of flow and transverse to the direction of flow. This ensures that the coolant flow is diverted in two planes, namely over the projections and around the projections, which produces particularly effective mixing of the coolant under laminar flow conditions.

Preferably the area of the tube walls occupied by projections amounts to less than 7.5% but more than 1% of the total area of the tube walls. Better results are achieved if the area of the tube walls occupied by projections amounts to less than 5%, and the best results obtained by the inventor at the time of preparation of this specification are achieved when the area of the tube walls occupied by projections amounts to approximately 2.5% of the total area of the tube walls.

For reasons of manufacturing practicality the projections will normally be formed in a regular or repeating pattern. The projections may be arranged in groups and within each group the projections can be arranged on a line extending across the tube. The projections on one wall can extend in a diagonally opposite direction to the line of projections on the other (opposing) wall.

Considered along an imaginary line which runs parallel to the length of the tube, projections on one wall may alternate with projections on the other wall. The alternating projections may be in line or may be offset relative to an imaginary line parallel to the tube axis.

The projections on one wall can be greater in number than the projections on the other (opposing) wall.

The tube may be formed from any suitable material, for example metal or a plastics material. A preferred material is aluminium or an aluminium alloy and the tube is preferably formed from sheet material and is formed into a tube by a longitudinally extending weld, with the weld seam running along one edge of the tube which joins the two major walls, after the tube has been flattened. However, the tube could be formed by other means, for example extrusion or pre-casting, and the weld seam of the tube (if welded) could extend in other directions.

The projections preferably take the form of dimples or indentations formed in the outer surface of the tube walls, to appear as projections in the internal cross-section of the tube. The projections can be generally square in plan view, but a wide variety of non square shapes is also possible. For example the projections may have a length greater than their width, and in this case the length of the projections can be set at an angle to the length of the tube. Although it is preferred that the projections are generally square or rectangular in plan view, there may be benefits from having projections which are oval or circular in plan view; for example circular indentations may help promote laminar flow while still permitting mixing. Oval indentations may help promote directional flow depending on the orientation of the axes.

Ends of each tube can be free from any indentations formed in the external tube surface, so that the tube ends can be

reliably sealed into heat exchanger header tanks without any potential leak paths resulting from indentations lying within the tube/header tank joint area.

The invention also provides a heat exchanger having a heat exchange core comprising a plurality of parallel coolant tubes separated by heat exchange fins, wherein each of the tubes has a flattened cross-section with two major opposing walls and internal projections on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube, wherein each projection extends across less than 30% of the width of the tube and the area of the tube walls having projections amounts to less than 7.5% of the total area of the tube walls.

In another aspect, the invention provides a method of operating a heat exchanger in which coolant is conveyed through tubes, wherein each tube has a flattened cross-section with two major opposing walls and internal projections on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to an extent such that laminar coolant flow is maintained within the tube over the normal operating range of the heat exchanger.

The laminar flow preferably follows a path which is diverted from wall to wall and from side to side between the tube walls. This ensures excellent mixing of the coolant without disturbing the laminar nature of the flow.

The invention will now be further described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a scrap view showing one part of a conventional heat exchanger construction;

Figure 2 is a cross section through a prior art heat exchanger tube;

Figure 3 is a perspective view of a tube in accordance with the invention;

Figures 4 and 5 show alternative cross-sections on the line IV,V-IV,V;

Figure 6 is a plan view of the tube of Figure 3;

Figure 7 is a plan view of part of an alternative form of tube in accordance with the invention; and

Figures 8 and 9 are sections taken on the lines VIII-VIII and IX-IX from Figure 3 to illustrate flow patterns in the tubes in accordance with the invention.

In Figure 1 a typical motor vehicle radiator is shown. The radiator has a heat exchange core or matrix 10 connected to a header tank 12. The core 10 consists of a number of parallel coolant tubes 14 with heat exchange fins 16 of concertina form mounted between the tubes 14 and in heat exchange contact with the tubes. In use,

coolant flows into the header tank 12 and from the header tank through the tubes 14 to a similar header tank at the opposite end of the radiator. Air moves through the fins 16, and the heat of the coolant in the tubes 14 is given up to the air passing through the fins.

Figure 2 shows an enlarged cross sectional view through a tube 14. The tube is formed from thin sheet material of flattened cross-section but with slightly bowed major faces 18 and 20. The tubes are formed from initially flat material which is welded together by a longitudinal weld indicated at 22. Reference should be had to US Patent 4 470 452 in connection with the bowing of the major faces 18 and 20, which is somewhat exaggerated in Figure 2.

The tube 14 shown in Figure 2 has a smooth internal bore 24. If coolant flows along a tube 14 with a smooth internal bore, the coolant flow along the tube tends to be laminar or streamline flow. In this case there will be a region at the centre of the flow (indicated in dotted lines 26 in Figure 2) where the coolant has no inducement to make contact with the walls of the tube, and this region of coolant is therefore insulated from the heat exchange taking place at the tube walls by the body of coolant between the region and the tube walls. It is therefore clearly desirable to interfere with the coolant flow through the tube and to provide mixing of the coolant as it passes through the tubes, so that heat exchange takes place with all of the coolant, and uniform temperature distribution throughout the fluid is promoted.

The conventional approach to ensure mixing is to use so-called turbulator radiator tubes, one example of which is shown in US patent 4 470 452. Turbulator radiator tubes, as their name implies, produce turbulence in the flow which does enhance mixing. However the production of turbulence results in a resistance to flow which detracts from the performance.

Figure 3 is a perspective view of a tube in accordance with the invention. It is intended that coolant will flow through the tube as indicated by an arrow 28, and whilst passing through the tube will encounter projections 30a, 30b (Figures 4 and 5) which are formed on the internal wall of the tube by indentations pressed from the outside wall of the tube. The indentations are indicated by reference numeral 32 in Figure 3, and the corresponding projections by 30a and 30b in Figures 4 and 5.

Figures 4 and 5 illustrate alternative forms of indentation. In Figure 4 the indentations are round-bottomed, and in Figure 5 the indentations have a trapezoid cross-section. These sections are taken on the lines IV,V-IV,V from Figure 3. The preferred depth d for the indentations 30a, 30b is between 35 and 50% of the internal tube height.

It will be noted from Figure 3 that the greater part of the surface of the tube 14 is plain and not provided with indentations.

Although Figure 3 shows only side of the tube, the other side of the tube will also be provided with corresponding indentations 32. Figure 6 illustrates this with

indentations on the upper (as seen in the Figure) face of the tube being shown in solid lines with the indentations on the lower or underneath side of the tube being shown in dotted outline. The indentations on the upper face extend along a line which makes an angle of approximately 45° to the length of the tube, and the indentations on the lower face are arranged in a corresponding manner, but along a line which makes an opposite angle of 45° to that of the indentations on the upper face. The preferred range for such angles is 30 to 60°.

It will be noted that, in passing through the bore of the tube, the coolant flow will encounter first a projection from the lower face of the tube then a projection from the upper face then a projection from the lower face and so on. This ensures that the flow is mixed both in a direction at right angles to the major plane of the tube as well as in a transverse direction across the major plane of the tube. This is shown in Figures 8 and 9 where the arrows show streamline flow around and over the projections.

Figure 7 shows a smaller section of an alternative form of tube with indentations 132 which are elongated in form and have their long axis angled to the direction of coolant flow 28. As in Figure 6, the corresponding indentations on the lower face have the same form but follow a line which crosses the line of indentations on the upper face.

The invention is not limited to any particular form or arrangement of indentations, but it is expected that the indentations will be positioned in a regular array rather than a random array. The intention however is that the

presence of the indentations/projections in the tube should interrupt the coolant flow sufficiently to ensure mixing of the coolant within each tube but should not interfere with the flow so drastically as to prevent the flow being generally laminar or streamline in form.

Figure 8 illustrates the nature of this flow within a tube 14 past projections 30. When the incoming laminar coolant flow is interrupted by a projection 30, the flow will divert and pass around the projection. However since the distance between projections (seen in the longitudinal direction) is comparatively long, there will be sufficient time for the flow to resume its laminar form before it encounters the next projection whereupon diversion and therefore coolant mixing will take place again.

Figure 8 shows the flow pattern in one plane. It must however be appreciated that the flow is also constrained by the presence of the projections both above and below the plane shown in Figure 8, and therefore the diversion of the flow when encountering a projection will take place both laterally (as shown in Figure 8) and also perpendicularly (as shown in Figure 9) to the major plane of the tube.

The ends of each tube will preferably be formed without any indentations, so that those ends can be reliably sealed to a header plate 34 (Figure 1) where the tubes 14 communicate with the header tank 12. The fewer the indentations the lower the probability of leaks resulting from indentations coming in contact with the header joints.

In comparison with turbulator tubes as described in US patent 4 470 452, the number and area of projections which interfere with the coolant flow through the tubes is substantially reduced. This has benefits in

- increasing heat transfer between the coolant and the fins 16,
- reducing back pressure and therefore facilitating coolant flow through the tubes,
- simplifying manufacture and reducing tooling costs
- reducing potential leak paths between tube indentations and headers.

Typical tube dimensions for a radiator for a passenger vehicle with an internal combustion engine have a major axis dimension of about 26 mm and a minor axis dimension of about 2 mm. Each indentation 32 can have a dimension of 1-2 mm^2, and the area of the tube covered by indentations can amount to about 2.5% of the total tube surface area.

Tests can be carried out to determine the optimum configuration and form of the indentation, either through practical tests with different samples, or through computer modelling.

Claims

1. A tube (14) for conveying coolant through a heat exchanger (10), the tube having a flattened cross-section with two major opposing walls and internal projections (30) on the major opposing walls (18,20), the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube, characterised in that each projection (30) extends across less than 30% of the width of the tube and the area of the tube walls (18,20) having projections amounts to less than 7.5% of the total area of the tube walls.

2. A tube as claimed in Claim 1, wherein the area of the tube walls (18,20) having projections amounts to less than 7.5% of the total area of the tube walls and more than 1% of the total area of the tube walls.

3. A tube as claimed in Claim 1 or Claim 2, wherein the area of the tube walls (18,20) having projections amounts to less than 5% of the total area of the tube walls.

4. A tube as claimed in Claim 1 or Claim 2, wherein the area of the tube walls (18,20) having projections amounts to approximately 2.5% of the total area of the tube walls.

5. A tube as claimed in any preceding claim, wherein the projections (30) are in the form of dimples (32) formed in the tube walls (18,20), the dimples having substantially equal dimensions in the direction of coolant flow and transverse to the direction of flow.

6. A tube as claimed in any preceding claim, wherein the projections (30) are arranged in groups and within each group, the projections are arranged on a line extending diagonally across the tube.

7. A tube as claimed in Claim 6, wherein the line of projections (30) on one opposing wall (18) extends in a diagonally opposite direction to the line of projections (30) on the other opposing wall (20).

8. A tube as claimed in Claim 6 or Claim 7, wherein the projections (30) on one opposing wall (18) are greater in number than the projections on the other opposing wall (20), and the projections on the one wall (18) are offset across the width of the tube from the projections on the other opposing wall (20).

9. A tube as claimed in any preceding claim, wherein the projections (30) are in the form of indentations (32) punched out from one surface of the tube to appear as projections in the internal cross-section of the tube.

10. A tube as claimed in any preceding claim, wherein the projections (30) are generally square or rectangular in plan view.

11. A tube as claimed in any preceding claim, wherein the projections (30) have a length greater than their width, and the length of the projections is set at an angle to the length of the tube.

12. A tube as claimed in any one of the preceding claims, wherein the depth of the projections (30) is between 35 and 50% of the internal diameter of the tube.

13. A heat exchanger having a heat exchange core (10) comprising a plurality of parallel coolant tubes (14) separated by heat exchange fins (16), wherein each of the tubes (14) has a flattened cross-section with two major opposing walls (18,20) and internal projections (30) on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube, characterised in that each projection (30) extends across less than 30% of the width of the tube (14) and the area of the tube walls having projections amounts to less than 7.5% of the total area of the tube walls.

14. A method of operating a heat exchanger in which coolant is conveyed through tubes (14), wherein each tube (14) has a flattened cross-section with two major opposing walls (18,20) and internal projections (30) on the major opposing walls, characterised in that the projections (30) extend into the internal cross-sectional area of the tube (14) to an extent such that laminar coolant flow is maintained within the tube over the normal operating range of the heat exchanger.

15. A method as claimed in Claim 14, wherein the laminar flow follows a path which is diverted from wall to wall and from side to side between the tube walls.

Fig. 1

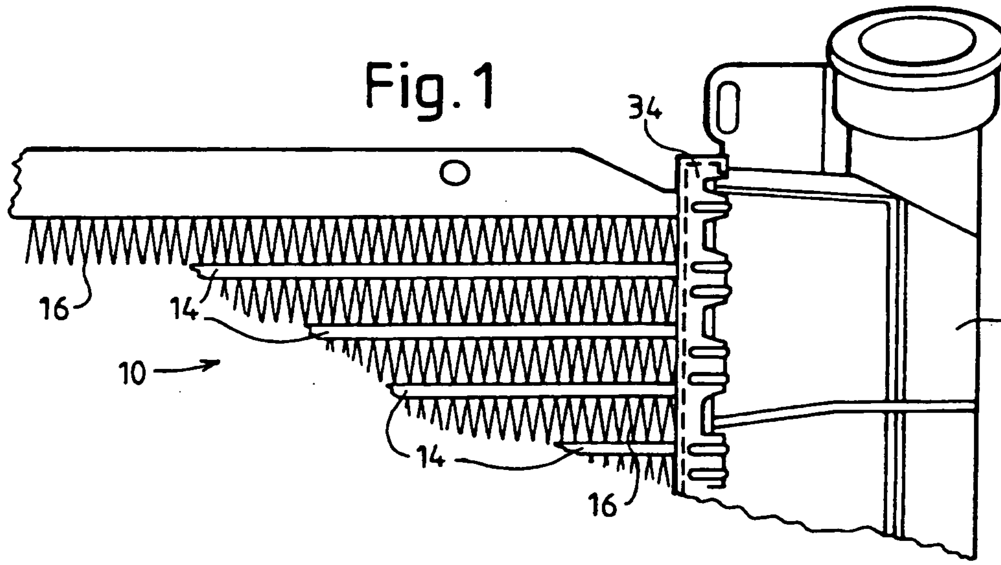
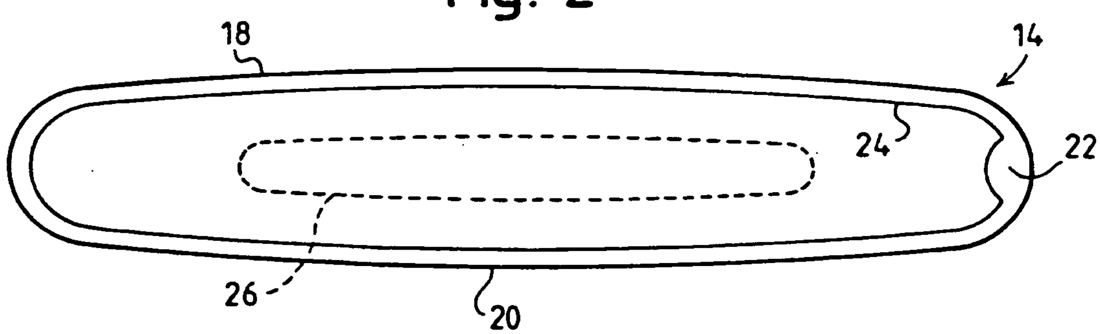


Fig. 2



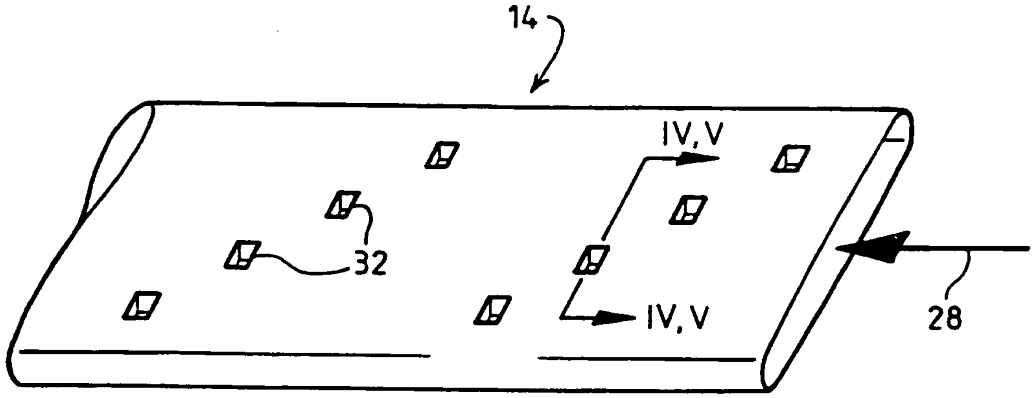
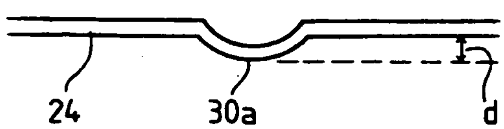


Fig. 3

Fig. 4



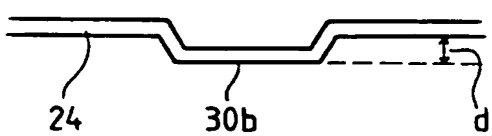


Fig. 5

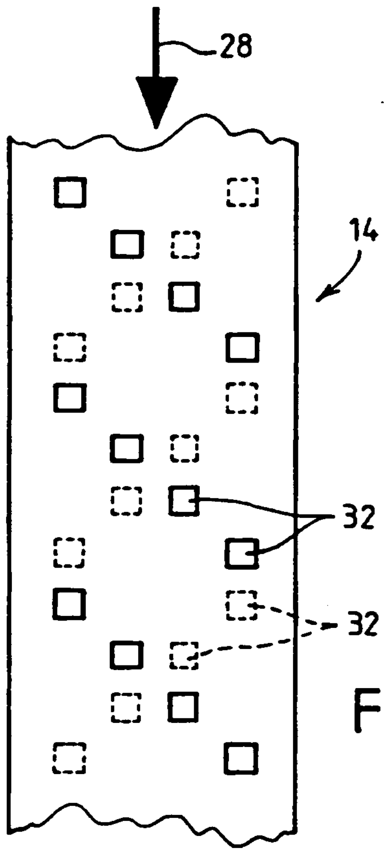


Fig. 6

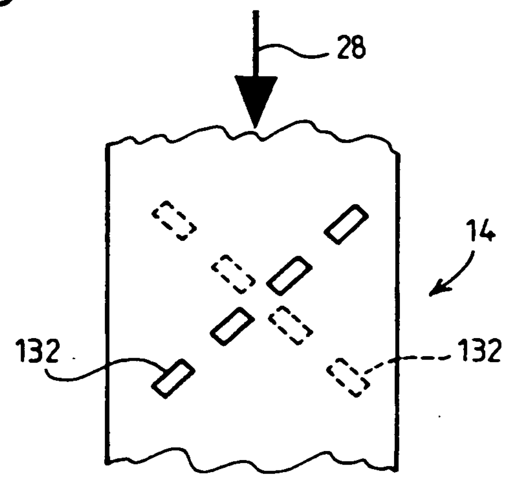
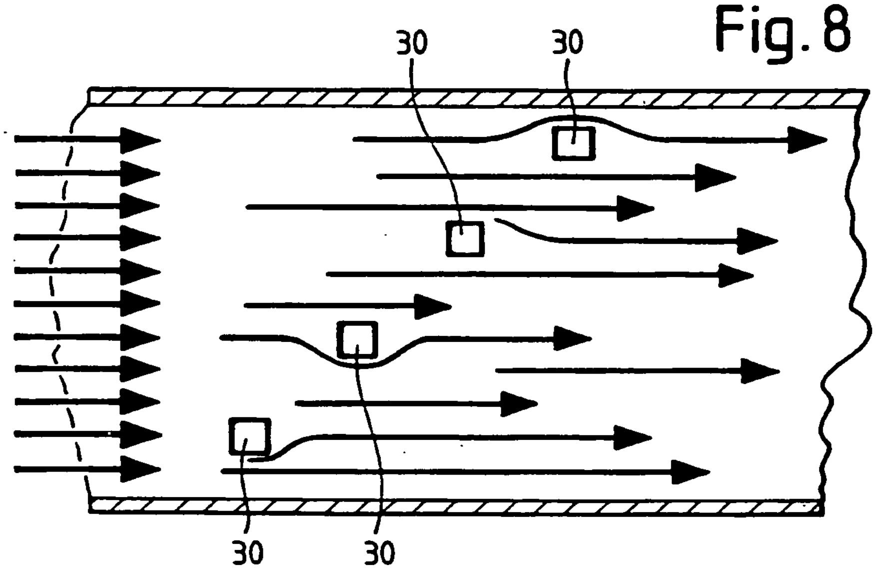


Fig. 7

Fig. 8



INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 00/02152

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F28F1/42

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F28D F28F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 012, no. 218 (M-711), 22 June 1988 (1988-06-22) -& JP 63 017393 A (NIPPON DENSO CO LTD), 25 January 1988 (1988-01-25) abstract page 455, column 1, line 30 - line 37; figures	1-5,9, 10,12,13
X	WO 98 44305 A (CREARE INC) 8 October 1998 (1998-10-08) page 18, line 14 - line 23; figures	14,15
A	US 5 730 213 A (KISER CARL E ET AL) 24 March 1998 (1998-03-24) column 4, line 19 -column 5, line 11; figures 4-9	1-13

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
8 September 2000	22/09/2000

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

Intern   ıal Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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A	US 4 470 452 A (RHODES EUGENE E) 11 September 1984 (1984-09-11) cited in the application abstract; figures ---	1-13
A	DE 295 09 684 U (BBK BLECHBEARBEITUNG & KOMPONE) 9 November 1995 (1995-11-09) page 6; figures -----	1-13

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 00/02152

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